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OBITUARIES

Charles McLean Fraser

1872-1946

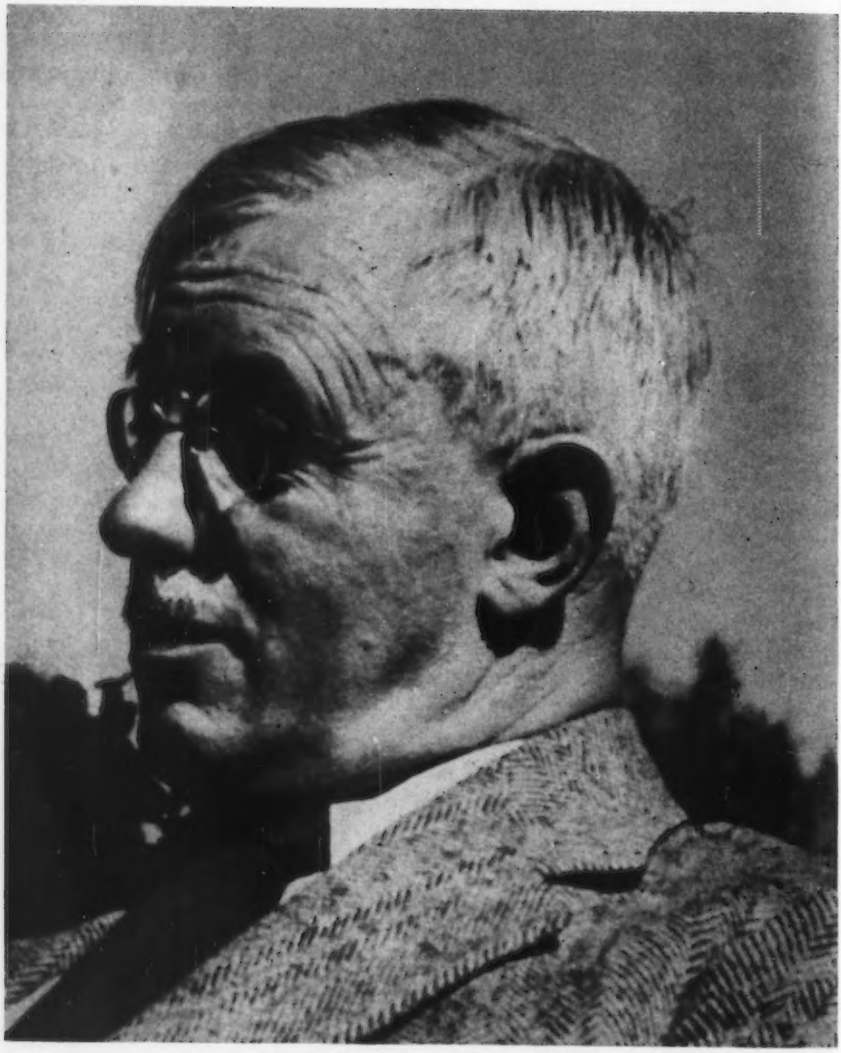
The death of Dr. Fraser breaks another link in the chain connecting the Fisheries Research Board of today with its early humble beginning. Charles Fraser, then a graduate student in the Department of Zoology at the University of Toronto, spent the summers of 1901 and 1902 at Canso, Nova Scotia, as one of the voluntary investigators in the small movable laboratory of the Atlantic Biological Station, established in 1889. There began an association with the Biological Board (now the Fisheries Research Board) which continued more or less intimately for about thirty years.

In the spring of 1903 he went to the west coast. He spent the summers of 1908 and 1909 at the newly established Pacific Biological Station at Nanaimo, where he collected and studied various marine animals, including hydroids. In 1912, he became Curator of the Pacific Biological Station, and for eight years was in year-round residence there, but on becoming Professor of Zoology at the University of British Columbia in 1920, he resided at the Station in the summer months only until he resigned the Directorship of the Station in 1924. During succeeding years he carried out a number of summer investigations, the last being in 1935 when he undertook a survey of the marine fauna of the Queen Charlotte islands. Dr. Fraser's contribution to the advancement of the work of the Board has been extensive. While resident director he made studies of the herring and salmon fisheries of the strait of Georgia. This was pioneer work and constituted the beginning of fisheries research on the British Columbia coast. In 1915-16, he was a member of the Sea-Lion Commission. But his main interests lay with the invertebrates and it was in this sphere that he made his outstanding contributions. The hydroids continued as his special field throughout his life, resulting in a large number of scientific papers and three books. As a result of the extensive use of the drag-dredge, he obtained a vast amount of information as to the occurrence and distribution of the bottom fauna of the strait of Georgia. The work involved in the dredgings was arduous for all was carried out with a hand winch operated from a small 12-foot motor boat, the "Snipe," or the 25-foot motor launch, the "Ordonez". The materials obtained formed the basis of the museum collections at the Biological Station and at the University.

The extent of Dr. Fraser's scientific activities are revealed in the publication of over 125 papers and books. In addition to these direct contributions, Dr. Fraser, because of his knowledge and enthusiasm, was able to lead graduate students and senior investigators to undertake studies of various invertebrate groups. The earlier issues of "Contributions to Canadian Biology" are evidence of the activities of the Station workers of this period.

The Fisheries Research Board in particular and the scientific world in general is deeply indebted to Dr. Fraser for his contributions to the advancement of scientific knowledge.

W. A. CLEMENS



ALEXANDER THOMAS CAMERON

1882-1947

In the recent death of Dr. A. T. Cameron, Canada has lost one of her most outstanding scientists, a genius for organization of scientific research, a gifted educator; Canadian life has lost a colourful figure and a citizen of the world. He was a Scotsman, born in England, educated in Scotland, England and Germany. He lived his adult life in Canada where he became more Canadian than many Canadian born but his outlook was international and withal he remained a Scotsman. Born in London, 1882, he received the B.Sc., M.A. and D.Sc. degrees from Edinburgh in 1904, 1906 and 1925. He came to Canada in 1909 as Lecturer in Physiology at the University of Manitoba, rose through the usual stages to Professor of Biochemistry in 1923 and remained in that position until his death on the 25th September, 1947.

As a scientific investigator Cameron's career began in Sir William Ramsay's laboratory in physical chemistry. A dozen papers and two books followed. In Canada his major work was concerned with iodine metabolism and the action of the thyroid. A long series of papers over a period of thirty years made significant contribution to this field. At the same time investigations were carried out in many other phases of biochemistry: Graves' disease, tar-induced cancer, gall stones, plasma proteins, adrenal action in starvation, the sweetness of sugars, and alcohol tolerance.

He was active in many scientific organizations, particularly the Royal Society of Canada, of which he was a fellow for twenty-five years and President of Section V in 1930. But his genius for organization came to the fore in the Fisheries Research Board. He was appointed to the Biological Board in 1928, became Chairman in 1934 and actively pursued its work until his death. In the years just preceding his Chairmanship the Board emerged from a rather academic organization into a broad field of fisheries research. During Cameron's regime these advances were consolidated and extended. Investigations on salmon, herring, ground fish, lobsters and shell fish were expanded, yielding important results. Work on chemistry, bacteriology and engineering was much enlarged and highly significant information on vitamin oils and on the preservation and curing of fish was obtained.

During Cameron's chairmanship two new stations were established, at Grand River, Que., and at Winnipeg. The operating budget to cover all work of the Board in Cameron's first year as Chairman was approximately $175,000, in his last year in office it was approximately $800,000; in his first year in office the Board employed thirty-four scientists and fifty-four other ranks, in his last year there were one hundred and ten scientists and one hundred and fifty other ranks.

Official recognition of this work of organization came to him in the form of a C.M.G. in 1946.

Cameron was a man of strong convictions, indomitable will, tireless energy and sterling honesty. He was completely intolerant of half-measures. It was not always easy to work with such a personality but anyone capable of standing the pace was immeasurably stimulated. Canada was enriched by his life, his work, his organizations, his example continues and some of his personality lives on in his many co-workers and associates.

G. B. REED

A Snail Commensal with the Soft-shell Clam

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(*Received for publication November 10, 1947*)

ABSTRACT

In gulf of St. Lawrence areas *Odostomia trifida* Totten lives commensally the year round on the siphon ends of the soft-shell clam, *Mya arenaria* L.

In the autumn of 1943, when the writer was examining a soft-shell clam, (*Mya arenaria* L.), from Bideford river, P.E.I., he found several small snails apparently of a single species of *Odostomia*, adhering to the end of the siphon close to its openings. At that time the association was regarded as probably adventitious. However, the same peculiar relationship was observed in the field in 1944 and repeatedly since then during the open water seasons at various points in Bideford river, at Souris, P.E.I., and at Shippegan and Tracadie, N.B.

So far the relationship has not been observed in clam areas on the outer coasts of Nova Scotia and New Brunswick and is not expected there because Whiteaves (1901) describes the snail as occurring only in the gulf of St. Lawrence.

In March, 1947, a sample of 50 clams was fished from Bideford river through a hole in the ice, which was about 60 cm. thick at that time. These were shipped alive to St. Andrews, N.B., for examination. Only one snail was found and it was attached to a clam siphon.

A study of clam beds in summer shows that the snails are found chiefly on clam siphons and occasionally on the very edge of clam burrows, but not otherwise free on the bottom. As many as thirteen snails, ranging in length from 1 to 3 mm., have been found on a single clam. As the clam extends and contracts its siphon in the burrow, the snails move up and down on it, making no attempt to escape. When the siphon contracts, the snails are largely hidden from view in the epidermal folds.

So far as the writer is aware this *Mya—Odostomia* association has never been described before. From what has been observed it is judged to be a form of commensalism that exists the year-round. It is not so very remarkable, because other species of *Odostomia* have peculiar parasitic or commensal relationships with other lamellibranchs including mussels and scallops, (Pelsener 1913, Lebour 1932 and Thorsón 1946). The radula which is so useful in feeding to most gastropods is lacking in species of this genus—a feature that is probably correlated with their aberrant life habits.

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The writer is grateful to Mr. W. J. Clench and Mr. R. W. Foster of the Museum of Comparative Zoology, Harvard College, who identified the snails from Bideford river as *Odostomia trifida*, Totten 1834. Specimens from the other areas appear to be specifically identical.

REFERENCES

LEBOUR, M. V. *J. Mar. Biol. Assoc. U.K.*, **18** (1), 117-121, 1932.
PELSENER, P. *C. R. Soc. Biol.*, **75** (2), 335-336, 1913.
THORSON, G. *Medd. Komm. Danmarks Havunds Fiskeri, Ser. Plankton*, **4** (1), 1-523, 1946.
WHITEAVES, J. F. Catalogue of the marine invertebrata of eastern Canada. *Geol. Sur. Can.* 1-271, 1901.

Action of Sulpha Compounds, Antibiotics and Nitrite on Growth of Bacteria in Fish Flesh

By H. L. A. Tarr and Catherine P. Deas
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ABSTRACT

Sodium nitrite (0.02%) inhibited growth more than sulphathiazole (0.001-0.002%) or sulphanilamide (0.002%), but penicillin G (5-75 I.U. per 100 g.) and streptomycin (100-10,000 "S" units per 100 g.) had no important effect.

These experiments were undertaken in order to establish the relative effectiveness of incorporated sulphanilamide, sulphathiazole, penicillin, streptomycin and sodium nitrite in retarding development of the mixed natural bacterial flora of fish flesh. It was previously found that, under certain conditions, nitrites exerted marked bacteriostatic action both in fish flesh (Tarr and Sunderland 1939a; Tarr 1940) and in culture media (Tarr 1940, 1942). Recent experiments have shown that ices containing quite small amounts of sulphathiazole or sulphanilamide (0.01 to 0.02%) delay bacterial development in flesh of whole iced fish (Tarr 1946, 1948) and have also verified previous findings (Tarr and Sunderland 1939b, 1940) that ice containing 0.1% of incorporated sodium nitrite is normally quite effective in this respect.

EXPERIMENTAL

The fresh fish employed were thoroughly scrubbed in running tap water in order to avoid possible heavy bacterial contamination of the flesh during subsequent filleting. The skinned fillets were passed through a Universal food chopper, the pH of a representative portion of the comminuted material being determined by means of a Beckman meter. A direct bacterial count (Tarr 1943) made of the minced flesh showed that initially it contained less than 100,000 bacteria per gram in all instances. North's stain (North 1945) was used instead of the usual Loeffler's stain in making the direct counts. Tests with both fish and meat have shown that somewhat higher counts are normally obtained with the North stain, and that the background of flesh material is less heavily stained than with Loeffler's stain. The North stain appears to deteriorate rather quickly.

Sulphathiazole (Merck), Penicillin G (Winthrop), Sulphanilamide (Eastman Kodak), Streptomycin hydrochloride (Merck) and sodium nitrite (C.P.) were employed. With the exception of sulphathiazole, which was dissolved in warm

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water, the compounds were dissolved in water at room temperature immediately prior to use. These bacteriostats were tested as follows.

Comminuted flesh (95 g.) was transferred to each of several 250-ml. sterile, covered glass beakers, and 5 ml. of water (in controls) or of aqueous solutions of

TABLE I. Effect of sodium nitrite, sulphathiazole, sulphanilamide and penicillin, on growth of bacteria in red spring salmon and lingcod flesh.

Treatment	Bacteria (millions per g.) by direct count				
	Red spring salmon (initial flesh pH, 6.2) after			Lingcod (initial flesh pH, 6.5) after	
	4 days	7 days	10 days	4 days	7 days
Controls	2	400	3700	6.2	950
0.02% sodium nitrite	0.13	4.6	99	1.2	68
0.001% sulphathiazole	0.80	20	710	3.0	40
0.002% sulphathiazole	0.90	21	870	3.5	49
0.002% sulphanilamide	0.64	40	1200	4.0	84
5 I.U. of penicillin G*	1.7	310	2000	3.1	610
20 I.U. of penicillin G*	2.2	390	2900	4.1	780
75 I.U. of penicillin G*	1.4	230	3800	5.4	870

*International units per 100 g. of fish flesh.

the bacteriostats in concentrations sufficient to cause the minced flesh to contain the quantities of these as recorded in tables I and II was uniformly incorporated by means of a heavy glass rod. The samples were stored at 0°C. At intervals the flesh was mixed thoroughly and 7.5-g. samples were removed and direct bacterial counts made.

TABLE II. Effect of sodium nitrite, sulphathiazole and streptomycin on growth of bacteria in red spring salmon and halibut flesh.

Treatment	Bacteria (millions per g.) by direct count					
	Red spring salmon (initial flesh pH 6.0) after			Halibut (initial flesh pH 6.15) after		
	7 days	11 days	16 days	7 days	11 days	16 days
Controls	0.27	260	4500	0.69	69	2700
0.02% sodium nitrite	<0.1	0.29	32	<0.1	0.95	12
0.001% sulphathiazole	<0.1	13	1600	<0.1	4.1	1200
100 "S" units of streptomycin*	0.27	350	3200	0.75	360	1900
1000 "S" units of streptomycin*	0.40	143	5100	0.45	220	4000
10,000 "S" units of streptomycin*	0.13	53	4000	<0.1	66	1500

*Streptomycin hydrochloride units per 100 g. of fish flesh.

The results of typical experiments with red spring salmon (*Oncorhynchus tshawytscha*), halibut (*Hippoglossus stenolepis*) and lingcod (*Ophiodon elongatus*) are recorded in tables I and II. In the lingcod samples, bacterial counts were not made after 10 days' storage because all the samples were obviously very stale. It will be seen that with this fish, bacteriostats which were effective with salmon and halibut afforded only a slight protection against bacterial spoilage. As suggested in previous publications (Tarr 1940, 1948), this may be due to the higher pH of lingcod flesh. Sodium nitrite was the most effective of the bacteriostatic substances investigated for salmon and halibut and also quite effective for lingcod. Sulphathiazole afforded a considerable degree of protection of these fish against bacterial spoilage, and appeared to be somewhat more active than sulphanilamide. No important decrease in the rate of bacterial increase in fish flesh was observed following incorporation of penicillin or streptomycin.

Organoleptic examination of certain of the samples showed that the nitrite-treated flesh invariably had a better colour and odour than the untreated flesh, and that this bacteriostat delayed the fading of the red astacin pigments of salmon. Sulphathiazole and sulphanilamide did not appear to prevent this fading but considerably delayed the development of unpleasant odours in the stored flesh, even with lingcod. Neither penicillin nor streptomycin was effective in delaying organoleptic spoilage.

REFERENCES

North, W. R. *J. Assoc. Off. Agric. Chem.*, **28**, 424-426, 1945.

Tarr, H. L. A. *J. Fish. Res. Bd. Can.*, **5**, 265-275, 1940.

J. Fish. Res. Bd. Can., **6**, 74-89, 1942.

J. Fish. Res. Bd. Can., **6**, 119-128, 1943.

Fish. Res. Bd. Can. Prog. Rep. Pac., **67**, 36-40, 1946.

J. Fish. Res. Bd. Can. **7**, (4), 155-161, 1948.

Tarr, H. L. A., and P. A. Sunderland. *Fish. Res. Bd. Can. Prog. Rep. Pac.*, **39**, 13-16, 1939a.

Fish. Res. Bd. Can. Prog. Rep. Pac., **41**, 15-16, 1939b.

J. Fish. Res. Bd. Can., **5**, 36-42, 1940.

Efficiency of Natural Propagation of the Pink Salmon (*Oncorhynchus gorbuscha*) in McClinton Creek, Masset Inlet, B.C.

By A. L. Pritchard
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(*Received for publication September 16, 1947*)

ABSTRACT

Through the medium of specially-designed counting fences, records have been maintained of the adult pink salmon, *Oncorhynchus gorbuscha*, spawning in McClinton creek, Masset inlet, B.C. from 1930 to 1942, of the eggs available for deposition each season and of the fry resulting from these eggs. A loss of 76.2 to 93.1 per cent of the potential egg deposition occurs between the time of upstream spawning migration and the egress of the fry to sea. This mortality is assigned to a number of factors, some of which are briefly discussed. Within certain limits and under reasonably uniform climatic conditions smaller egg depositions provide greater efficiencies of hatch (percentage relationship of numbers of fry migrants to potential egg deposition). There thus appears a tendency toward rebuilding the run, herein termed "resilience," and believed to be closely bound up with the relationship between the fish and its physical and biological environment.

In 1928, the Biological Board of Canada (now Fisheries Research Board of Canada) initiated an investigation of the life history of the pink salmon (*Oncorhynchus gorbuscha*) in British Columbia. The present paper reports on an experiment which was designed to give basic information on the natural propagation of the species. Pertinent data are submitted herein for the freshwater stage of the pink salmon's life while indicating the usual reaction of the fish to the many environmental conditions which might influence it during that period.

METHODS

To produce sound knowledge of a quantitative nature, the only reliable method of approach appeared to be to choose one area and one creek therein which had a pink salmon run and which, as far as could be discovered from qualitative examination, were representative of other districts and creeks which the species frequented. In this chosen location the specific population could be studied thoroughly over a period of years.

Masset inlet district (fig. 1) on Graham island, the most northerly of the Queen Charlotte group, was selected as a base for three reasons: (1)For a number of years this inlet had supported what was considered to be one of the most important pink salmon runs in British Columbia. (2)In this area the pink salmon appeared in large numbers in the even-numbered years *only*. Not one

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individual of the species had ever been authentically reported in the odd-numbered. An opportunity was thus afforded to test the feasibility of transplantation in building a run in the "barren" year (Pritchard 1938). (3) In a more or less enclosed inlet such as Masset, there was a reasonable chance of keeping a close check on the commercial fishery to determine just what effect

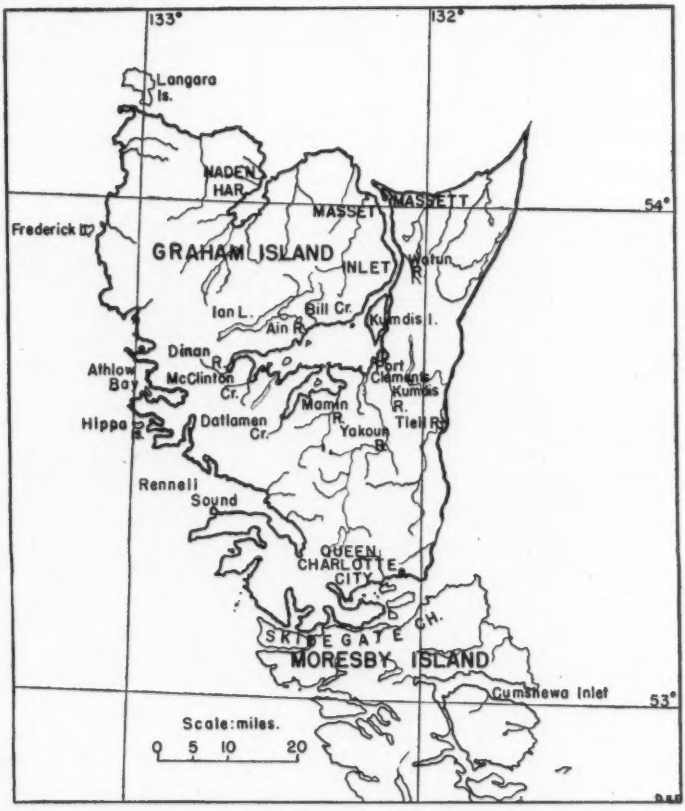

FIGURE 1. Graham island, Queen Charlotte islands, B.C. showing Masset inlet and tributary streams including McClinton creek.

this had on the escapement to the rivers through reduction of the numbers of spawners.

Following a general survey of the region, McClinton creek was chosen as a site for permanent location since it appeared reasonably typical of the streams in the area, supported a good natural run of pink salmon, and was of suitable size for observation of fish and for operation of the counting fences necessary in such an investigation. This stream, approximately four miles (1 mi. equals 1.60 km.) in length, takes its source in springs on the surrounding mountains,

the highest of which is about 2,800 feet (1 ft. equals 0.3 m.). The portion of the creek bed used for spawning extends for about 2.5 miles above tide water and consists of a series of gravel bars, a few stony riffles, and deep sandy-bottomed pools (fig. 2).

Above this area, the creek bed becomes rougher with many stones and boulders. In the upper reaches beyond a small falls, the stream gains elevation and loses size quickly until, at its main source, it is little more than a trickle.

Over the main spawning reaches there is some variation in width considered as a bank to bank measurement—50 to slightly over 100 feet. Actually, however, there is a great difference in the width of bed available for spawning at various periods since this is dependent on the amount of water and such small coastal rivers are subject to considerable fluctuation in volume directly related to

FIGURE 2. Typical gravel spawning bed in McClinton creek.

changes in precipitation. There are numerous small "feeder" tributaries, but these, except at freshet levels, are too small and precipitous to permit spawning. McClinton creek thus presents over a distance of 2.5 miles of its length excellent spawning beds of good gravel of variable width with sufficient deep resting pools.

The experiment designed to assess the efficiency of natural propagation in the fresh water phase of the life history and to reveal the factors affecting it, consisted mainly of three phases: (1) the counting of the adult salmon proceeding up-stream to spawn; (2) obtaining by actual count from a random sample of females the average number of eggs per individual (this, used with the total number of females, will allow the calculation of the potential egg deposition); and (3) enumerating the number of fry resulting from the seeding as they migrate to sea the following spring.

The *counting of the adult salmon* was accomplished by the use of a wooden

weir constructed across the stream at the head of tidal influence but below the the main spawning area. The operation of this structure has been fully described and illustrated in another paper (Pritchard 1936).

Since the *number of eggs in a female pink salmon* has been shown to rise with the length and weight (Foerster and Pritchard 1941), and because it has been demonstrated that the size of the fish increases throughout the progression of the spawning run (Pritchard 1937), certain refinements in method were necessary to guarantee that a random sample was being secured for egg counts. Having determined what would be a sufficient total number for the year, each day's quota, obtained by dipping females from either counting pen without any effort at selection, was determined as a proportion of the number migrating. As a check on the efficiency of the method in producing randomness, each year the average lengths and weights of the "egg" females were compared with those for the females in a much larger group which were measured and weighed alive. In no case was a significant difference demonstrable.

The *enumeration of fry migrants* was carried out through the use of a specially-designed screen fence installed on the same base as the wooden adult weir. A full description of this structure and its operation has been submitted previously (Pritchard 1944). Certain difficulties, directly attributable to the size of the migration and to weather conditions, made necessary three distinct methods of approach in order to gain an absolute count, namely, counting, weighing and estimating.

Counting which involved the actual enumeration of each individual, was employed in all cases when the nightly migrations were sufficiently small that they could be handled during the next day.

Weighing was used when the numbers were too large to be handled by counting. Briefly, this procedure included weighing the fry at usually two to three pounds (1 lb. equals 0.45 kg.) per weighing in a wire basket on an ordinary Pelouze dairy scale. Certain of the weighed groups were counted before release while others were dumped without counting. From the ratio obtained each day between weight and numbers, the total was calculated.

Estimation was invoked at times when the water was high because of freshet conditions so that it was necessary to remove the screens or run the risk of killing many migrants as well as damaging the fence beyond repair. Usually in such instances it was essential to have the screens out of the water for only *part* of the night but in some cases they were out for the *whole* period.

For this purpose of estimation of the complete nightly migration when the fence was only operated part of the time, use was made of the observations on fry migrations and graphs of a type recorded in a previous paper (Pritchard 1944, pp. 223 and 224), viz.:—

"the course of the nightly migration was discovered by manipulating the pens in the trap. At a given time all the fish were driven into the downstream compartment. Those arriving during the remainder of the night collected in the upstream section. Repeated experiments of this type showed that under normal conditions the fry began running rather slowly, in so far as numbers were concerned, immediately after dusk. Very quickly they attained a constant rate which was maintained throughout the period of darkness. As dawn approached, the concentration decreased

abruptly. If the percentages of the run which had occurred up to definite times were plotted against the percentages of the period between dawn and dusk which had been exhausted at the same times, a straight line at approximately forty-five degrees to the horizontal... gave the best fit for the several points. Thus, within the accuracy of the experiments, the number of migrants per hour on any given night was constant. The slight delay in starting at dusk and the decrease at dawn apparently had little effect on the general trend."

Thus, if the period after dusk when the screens had been in place was calculated as a percentage of the total time between dusk and dawn, direct reference to the graph for the specific year showed the percentage of the nightly run which had passed before the screens were lifted. From this percentage and the actual count of fish up to the time of screen removal the total night's population could be calculated.

On nights when the fence was out for the *whole* period, the estimate was reached by averaging the runs of the night previous and that succeeding.

RELIABILITY OF METHODS

The consideration of errors possible in all stages of the experiment is essential to assess the reliability of the final figures which are used as a basis for deductions and conclusions. For this reason each phase is treated briefly from that viewpoint.

In the *counting of the adult salmon* almost absolute accuracy can be expected since the fish are tallied and examined individually.

For the determination of *average egg count per female*, it has already been established that the sample used is random because the "egg" females do not differ significantly from the other females in the runs. The error which does accrue will arise from the effect which the variability of the individual counts may have on the mean. A measure of this variability is indicated by the probable error which amounts to less than 1% in all cases.

Fry counting error. In the counting manipulation, a number of fry—about three to four thousand—were emptied from a dip net into a shallow cheese cloth tray set in a trough filled with water (Pritchard 1939, figure 1, p. 236). From this they were dipped, three or four at a time, with a tablespoon, and counted into a deep wire basket suspended in the same trough. Checking involved having each crew of workers count a number which were then transferred to the troughs of an eyeing station on the premises. Some time later a recount was made. The difference between the two was accepted as the possible error. Each operator was subjected to the trial at one time or another but not every year.

From the results, it is apparent that, although at times a moderately large error may occur (maximum in tests 3.5 %) due to chance, accident, or variation in the efficiency of the individual, in the large number of fry handled over the season, there is compensation so that the final deviation is small. In 102,848 fry which were recounted, the difference amounted to 115 or approximately 0.1%.

Fry weighing error. In the method of weighing which has been fully outlined above, the same operator was detailed to carry out all the manipulations in as nearly as possible a similar manner each time. Efforts were made to keep each weight as close to three pounds as possible. For checking, certain weighed groups, which would ordinarily have been released without counting, were placed in the

hatchery troughs and later counted. The error was considered as the difference between the calculated number and the count.

The largest error in weighing (8.5%) occurred during the 1931 migration when the investigators were relatively inexperienced. This was mainly due to the fact, however, that at the time one check was made, there were large numbers of chum (*O. keta*) and coho (*O. kisutch*) salmon fry mixed with the pinks. A dipping might thus easily strike either large or small quantities of these "foreign" species which were bigger and heavier than the pinks. To reduce this discrepancy, in later years, weighing was utilized in so far as possible when the pinks were present in practically pure culture and counting was maintained when mixture was evident. The composite error may be considered as an average in this case since the same operator was involved year after year. Even including the sample above for which

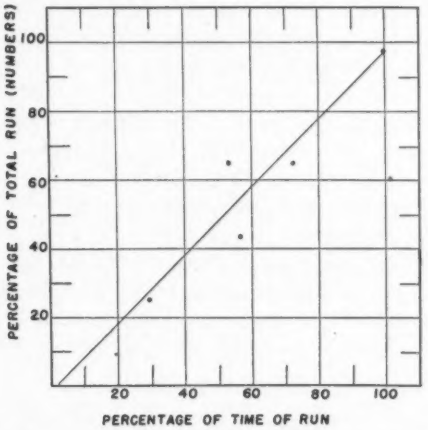

FIGURE 3. Course of nightly fry migration at McClinton creek.

the cause of the discrepancy was discovered and largely eliminated in later work, the difference in handling 216,225 fry was only 2,501 or 1.1%.

Fry estimation error. The error caused in the final calculation by the method employed in estimating the numbers of fry for the periods when the screens were out for part of some nights, is difficult to place with any degree of accuracy. From the sample calculation curve of nightly migration for 1931 published previously (Pritchard 1944) and reproduced in figure 3, it can be seen that the points obtained experimentally vary around a mean.

The *best* curve that can be fitted to the points is considered to be a straight line determined by the method of least squares. The representation, however, could vary from a curve which connected all the higher points on the plot to one which joined all the lower ones. The minimum estimates can thus be calculated by using the higher curve, the maximum by using the lower, and the "most probable" by employing the straight line. The most reasonable possible error is considered to be half the difference between the highest and lowest estimate.

To check the efficacy of this simplified method of treatment, the writer for some of the years has determined the correlation coefficient and plotted the regression line for the relationship between percentage of hours of darkness and percentage of run handled. On each side of this line, another has been set up to show the limit of an error which is twice the standard deviation. In every case twice the standard deviation is slightly smaller than the error calculated by using the upper and lower curves described above. The unrefined procedure has thus resulted in, if anything, a more restricted interpretation of the final figures.

The error caused by averaging the total of the previous and the succeeding day's counts to establish the escapement for the twenty-four hour periods when the fence *was out all the time*, can only be suggested from qualitative observations. It should be stressed that only relatively small numbers are involved except for the run of 1931, because the fence was completely removed in the majority of cases only early and late in the season when the migration included a few fish and no justification could be seen for causing unnecessary mortality or for damaging the structure beyond repair. When large numbers were moving, every effort was made to preserve the operation if only for a very short portion of the night. It has been proven beyond a doubt that the numbers in the run do not increase indefinitely as the water keeps rising. The author (Pritchard 1944, p. 225) states that: "with the increase in the size of the stream and the current, those which would ordinarily be in calm water are swept into the main flow whence they carry on their migration toward the sea. On the night of a freshet most of the young fish which are out of the gravel move downstream." "If a freshet took place in the daytime, there was no sudden influx of fish into the pens." Such observations have led to the belief that the average is at least a reasonable measure of the numbers which escaped.

RESULTS

The picket fence was installed in McClinton creek during the spring and summer of 1930 to handle the adult run of that season. Thereafter the spawning pink salmon were counted in each migration up to 1942, viz.—in the autumn of each even-numbered year—1932, 1934, 1936, 1938, 1940, and 1942. During the spring following each of these runs, except that of 1942, the fry resulting therefrom were determined at the screen weir. The experiment thus covered six complete cycles.

In order to show the logical development of the calculation and to submit the detail of the programme in proper sequence, the data obtained for the counts of spawning pink salmon and fry migrants are presented in the successive compilations—tables I to IV. Table I gives the counts of adults and the average numbers of eggs per female. Table II indicates the fry estimated and the writer's approximation of the possible error of the final figure. Table III presents the counts of fry for each year showing the portion counted, weighed and estimated. The last column lists the approximate possible error in the final figure after consideration of the individual errors which might accrue in each stage of the manipulation in obtaining the count. Table IV is really a combination of tables I and III to which has been added the "efficiency of hatch" or the percentage which the number of

fry from a given seeding constitute of the potential egg deposition. The figure recorded as "most probable" is in the opinion of the author the closest approach to the accurate. The range is submitted to indicate the possible variation which might have occurred due to experimental error.

The figures for the "efficiency of hatch" submitted in table IV leave no doubt whatsoever that the greatest absolute mortality in the life of the pink salmon occurs during its fresh water existence from the time of the upstream

TABLE I. Summary of the counts of spawning salmon at McClinton creek from 1930 to 1942 including the total number of males and females reaching the fence, the numbers taken as samples, the net spawning population, the average number of eggs per female and the potential egg deposition. The figures for such deposition submitted here will be slightly lower than those given in other papers (e.g. Pritchard 1940 p. 238) since they have been adjusted for the number of samples taken.

Year	Total run		Samples		Net spawning population		Eggs per female (av. no.)	Potential egg deposition
	Male	Female	Male	Female	Male	Female		
1930	32,955	33,198	36	91	32,919	33,107	1,535 ± 12	50,800,000
1932	8,003	7,597	7	66	7,996	7,531	1,758 ± 15	13,200,000
1934	77,477	77,719	14	166	77,463	77,553	1,799 ± 11	139,500,000
1936	24,221	28,091	3	93	24,218	27,998	1,899 ± 12	53,200,000
1938	5,549	5,028		40	5,549	4,988	1,698 ± 19	8,500,000
1940	19,071	16,450		41	19,071	16,409	1,619 ± 17	26,600,000
1942	17,574	19,319		61	17,574	19,258		

TABLE II. Numbers of fry estimated at McClinton creek from 1931 to 1941 during the periods when the screens were removed for part or all of a night. Calculations for partial nights' operation have been made on the basis of graphs for each year similar to figure 3. The maximum is determined by using the curve connecting the lowest points in these graphs, the minimum from the curve connecting the highest and the "most probable" from the straight line in the middle. Calculations for nights when the fence could not be operated were reached by averaging the count for the night previous and that for the night succeeding. These latter are included in the most probable figure.

Year	Night screens out		Possible count			Approx. possible error in most probable count (%)
	Partial	Complete	Minimum	Most probable	Maximum	
1931	10	4	896,000	1,504,000	2,332,000	47.7
1933		2		5,000		?
1935	8	1	2,866,000	3,461,000	6,308,000	49.7
1937	3	6	375,000	418,700	468,000	11.1
1939	8	6	146,000	200,000	269,000	30.7
1941		3		30,000		?

TABLE III. Fry migrants counted, weighed and estimated, the total runs and the possible error in the operations, for the six downstream migrations at McClinton creek from 1931 to 1941. The error is calculated by allowing 1% for weighing, the amounts submitted in table II for estimating and figuring the percentage this amount is of the total run as given.

Year	Counted	Weighed	Estimated	Total	Estimated approx. possible error (%)
1931	2,890,094	989,566	1,504,000	5,384,000	13.5
1933	1,486,371	813,364	5,000	2,300,000	.2
1935	3,179,249	5,968,359	3,461,000	12,600,000	14.1
1937	1,704,631	1,551,578	418,700	3,675,000	1.7
1939	1,308,219	514,570	200,000	2,020,000	3.3
1941	2,036,969	2,995,746	30,000	5,060,000	1.2

TABLE IV. Summary of propagation counts (freshwater phase) at McClinton creek for the six life cycles between 1930 and 1942 showing potential egg deposition, numbers of fry resulting from each, and percentage efficiency of hatch,—most probable and range. This efficiency is the percentage which the fry migrants constitute of the potential egg depostion.

Cycle	Potential egg deposition	Fry migrants	Efficiency of hatch (%)	
			Most probable	Possible range
1930 - '31	50,800,000	5,384,000	10.6	9.4 - 12.2
1932 - '33	13,200,000	2,300,000	17.4	
1934 - '35	139,500,000	12,600,000	9.0	8.6 - 11.1
1936 - '37	53,200,000	3,675,000	6.9	6.8 - 7.0
1938 - '39	8,500,000	2,020,000	23.8	23.2 - 24.6
1940 - '41	26,600,000	5,060,000	19.0	

movement of the adults in the autumn until the end of the downstream migration of the fry in the spring. The loss during this stage varies from 76.2 to 93.1% of the potential egg deposition. It is interesting to compare these figures with those determined for the sockeye salmon at Cultus lake, British Columbia (Foerster 1936, p. 9). This species (*O. nerka*) spends almost a full additional year in the fresh water lakes and the loss, up to that time has amounted to 96.84 to 98.95% of the eggs available for deposition.

In figure 4, the "most probable" efficiency of hatch is plotted against the potential egg deposition for the six years which have been investigated. A curve to fit these points has been drawn by eye (solid line). The dotted line fitted in the same way shows the relationship between potential egg deposition and the absolute numbers of fry.

In drawing deductions from this graph, the fact has been borne in mind that the curve merely depicts a generalized relationship over a moderately long period and that extreme variations in certain years have been smoothed out. It would appear from the trend, however, that a greater efficiency is usually obtained from the smaller egg depositions. In 1930, 1934 and 1936, with depositions ranging from approximately 50 million to 139 million eggs, the percentages were low,

varying from 6.9 to 10.6. For the runs of 1932 and 1940 with depositions of about 13 and 27 million respectively, the values were high but intermediate, viz.—17.4 and 19.0. The smallest seeding of 1936, 8.5 million eggs, gave the greatest efficiency of 23.8. In view of the fact that the 50 million and 139 million produced the same general range of percentage efficiency, it is suggested that there may be an upper limit for deposition above which the percentages will not drop except in cases where the effects of extreme overcrowding might assume a major role. On the other hand, there may be a minimum number of spawners below which the efficiency will drop to a very low point because of inefficient and insufficient fertilization. Apparently neither of these extremes has been encountered in the

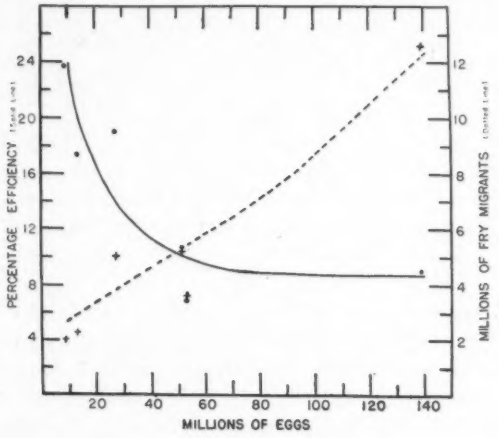

FIGURE 4. Relationship between (1) potential egg deposition and percentage efficiency of hatch (solid line) and (2) potential egg deposition and numbers of fry migrants (interrupted line) at McClinton creek from 1930 to 1941.

six runs at McClinton creek. A general premise might be stated as follows: *within certain limits*, which are indicated but which have not yet been encountered at McClinton creek, *and under reasonably uniform climatic conditions, the smaller seeding of pink salmon will generally provide the greater efficiency of hatch.*

It should be remembered that efficiency of hatch refers to a proportion which the fry migrants constitute of the potential egg deposition and *not* to the absolute numbers of these fry migrants. In figure 4 these absolute numbers have been plotted against the egg depositions (dotted line). There is no denying the fact that an increased return in fry is indicated for increased egg depositions. The rate of increase changes, however. For instance, in 1938, 8½ million eggs produced almost as many fry as the 13 million in 1932. If the greater efficiency had been maintained, there should have been approximately 3,100,000 fry in the spring of 1933 instead of 2,300,000.

DISCUSSION

The variation in the "efficiency of hatch" from year to year is undoubtedly due to the change in the interrelationships of those factors—environmental and biological—which may affect spawning, incubation and alevinage.

In a recent paper, the writer (Pritchard 1947) has discussed briefly the many factors which may affect the natural propagation of salmon and result in losses. For the pinks the most important during the fresh-water life appear to be the following: (1) Predation on adult spawning salmon; (2) incomplete spawning; (3) predation on the eggs; (4) dislodging and destruction of eggs due to superimposition by later runs; (5) destruction of eggs from the erosion of the beds due to freshets; (6) deleterious effect of climate and the resulting environmental conditions on the spawning incubation and alevinage; (7) predation on the fry migrants.

The investigation of the relative contribution of each of these factors has been deemed sufficiently important to warrant a separate more or less extensive study the results of which will shortly be reported by Mr. W. M. Cameron. At the present, however, it is not difficult to see how variation in their effect and their interrelationship could cause a change in efficiency from year to year. The absolute numbers of predators and their activity may vary and thus the effect of predation may change. The completeness with which the females spawn is not likely to differ significantly except in the case of a major catastrophe such as has only occasionally been recorded. Dislodging and destruction of eggs due to superimposition will depend on the size of the run, its distribution in point of time and the available spawning area. Conditions such as water height and current, which are the direct result of the climate, although generally similar from year to year, certainly do vary in the time and force of their incidence. They thus have a major role in setting up conditions favourable for or deleterious to the action of all the limiting factors and in causing conditions which may be destructive at any particular and crucial period.

One of the chief causes of variation in efficiency of hatch from cycle to cycle at McClinton creek is the climatic conditions affecting the water height in the river. It has already been demonstrated (Pritchard 1936) that the number of adult pink salmon migrating daily from the sea to the spawning grounds is positively and very significantly correlated with both the maximum daily water height in the stream and the rainfall in the region. Exploratory examination indicates that it is essential to have fairly heavy rainfall in August, September and early October of the spawning year if a good return in fry and adults is to result. Davidson and Hutchinson (1943) have indicated the possible effect of rainfall and low temperatures in controlling the size of pink salmon runs in the streams of southeastern Alaska. Such relationships are not unexpected since there must be sufficient water in the autumn to permit the mature fish to reach the spawning beds and it is preferable that there be enough to allow fairly wide spreading over the good gravel. If, on the other hand, the water is so high that it covers the higher bars, the fish will spawn on them. Later in the season, the water usually drops. While there may still be enough seepage underneath the gravel to keep the eggs in the redds wet and allow them to incubate, unless the stream reaches

the same height in the spring, the fry will not be able to escape. In addition, in coastal streams such as McClinton, which are subject to "flash" floods in which the water suddenly rises as a result of heavy rain and almost as quickly recedes, the conditions may be repeated over and over again during the season and have not only the repeated wetting and drying but also a scouring effect at critical periods during spawning, incubation and alevinage.

One very important point appears to have been demonstrated by the experiment, namely that there exists in the case of the natural propagation of pink salmon a condition which might be termed "resilience". In other words, if the numbers of spawners and thus the egg deposition is reduced, there is increased propagation efficiency which reacts toward again building up the run. Although the condition has been demonstrated, the exact cause or causes therefor are not definitely fixed at the present time but it would seem that they are bound up with the relationship between the fish and its environment—both physical and biological. It is possible that when the numbers of spawning salmon are reduced, certain limiting factors become less intense in their action, e.g. the run occupies more suitable and desirable sites and the detrimental effects of superimposition are lessened. It could also be that with lowered numbers and decreased population density, a change occurs within the fish themselves.

SUMMARY

As a result of experiments carried out on the run of pink salmon at McClinton creek, Masset inlet, from 1930 to 1942, it has been discovered that the return in fry migrants from the potential egg deposition may vary from 6.9 to 23.8%. The loss 76.2 to 93.1% may be due to a number of factors amongst which are: predation on adult spawning salmon, incomplete spawning, predation on eggs, dislodging and destruction due to superimposition by later runs, destruction of eggs through erosion due to freshets, the deleterious effects of climate and the resulting environmental conditions on spawning, incubation and alevinage, and predation on fry migrants. The severity of such losses varies from year to year with the changing effect of conditions which control the interrelationships of these factors.

Within certain limits and under reasonably uniform climatic conditions, it appears that smaller egg depositions will provide greater efficiencies of hatch (percentage relationship of number of fry migrants to potential egg deposition). This condition or tendency to react toward again building up the run, has been termed "resilience" and appears to be bound up with the relationship between the fish and its physical and biological environment.

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The experiments described were carried out over a long period during which many persons made definite contributions. Particular thanks are due to Dr. W. A. Clemens who, in his capacity of Director of the Pacific Biological Station, was always ready to advise in the scientific problems and help with the administrative difficulties. Dr. R. E. Foerster, the present Director of the Pacific Bio-

logical Station, gave unreservedly of the information gained through long experience with such programmes at Cultus lake, B.C. The writer's associate in the later years of the experiment, Mr. W. M. Cameron, provided great stimulus in addition to physical help. Special tribute should be paid to the two foremen during the period, Messrs. J. H. Stannard and D. E. Maxwell, for their unfailing interest and labours unstintingly given at all times.

REFERENCES

DAVIDSON, F. A., AND S. J. HUTCHINSON. Weather as an index to abundance of pink salmon. *Pacific Fisherman*, **43** (6, 7) 21-29, May 1943.

FOERSTER, R. E. Sockeye salmon propagation in British Columbia. *Bull. Biol. Bd. Can.*, **53**, 1-16, 1936.

FOERSTER, R. E., AND A. L. PRITCHARD. Observation on the relation of egg content to total length and weight in the sockeye salmon (*Oncorhynchus nerka*) and the pink salmon (*O. gorbuscha*). *Trans. Roy. Soc. Can.*, **35**, Sect. V, 51-60, 1941.

PRITCHARD, A. L. Factors influencing the upstream migration of the pink salmon (*Oncorhynchus gorbuscha*). *J. Biol. Bd. Can.*, **2** (4), 383-389, 1936.

Variations in the time of run, sex proportions, size and egg content of adult pink salmon (*Oncorhynchus gorbuscha*) at McClinton creek, Masset inlet, B.C. *J. Biol. Bd. Can.*, **3** (5), 403-416, 1937.

Transplantation of pink salmon (*Oncorhynchus gorbuscha*) into Masset Inlet, B.C. in the barren years. *J. Fish. Res. Bd. Can.*, **4** (2), 141-150, 1938.

Homing tendency and age at maturity of pink salmon (*Oncorhynchus gorbuscha*) in British Columbia. *J. Fish. Res. Bd. Can.*, **4** (4), 233-251, 1939.

A study of the natural propagation of the pink salmon, *Oncorhynchus gorbuscha*, in British Columbia. *Trans. Amer. Fish. Soc.*, **69** (1939), 237-239, 1940.

Physical characteristics and behaviour of pink salmon fry at McClinton creek, B.C. *J. Fish. Res. Bd. Can.*, **6** (3), 217-227, 1944.

Fish cultural problems involved in the conservation of anadromous fish with particular reference to salmon on the Skeena river, B.C. *Canad. Fish. Culturist*, **1** (2), 8-13, 1947.

Control of Rancidity in Fish Flesh
II. Physical and Chemical Methods

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ABSTRACT

Storage of frozen fish in high partial pressures of carbon dioxide or nitrogen effectively prevented fat oxidation and organoleptically detectable rancidity. Carbon dioxide stored fish developed an undesirable flavour not observed in that stored in nitrogen. Ice glazes formed from water or ethyl gallate solutions were about equally effective in delaying fat oxidation in frozen salmon steaks or fillets, but considerably less effective than l-ascorbic acid or sodium l-ascorbate glazes. Immersing salmon steaks or fillets in l-ascorbic acid or sodium l-ascorbate solutions strongly inhibited fat oxidation. l-Ascorbic acid and closely related compounds were as effective, or more effective, than ethyl gallate or several other gallic acid derivatives for frozen fish. When l-ascorbic acid was added to fish flesh its concentration fell rapidly at first, and then very slowly in the frozen fish.

The comparative value of a number of incorporated chemical antioxidants in delaying the onset of rancidity in indigenous fats of fish flesh was previously determined (Tarr 1945, 1947). The present paper describes experiments in which physical and chemical methods, alone or combined, have been investigated in order to assess their ability to retard fat oxidation in fish flesh.

Physical methods of retarding rancidity development in cold stored fish which are in use commercially include such common practices as the ice glazing of frozen whole single fish, or blocks of small fish, and the wrapping of fillets or steaks in certain moisture-proof papers. These methods are probably employed more with the object of preventing desiccation than of delaying fat oxidation, but there is little doubt that they do assist in retarding the development of rancidity.

EXPERIMENTAL

The methods of incorporating antioxidants into minced fish flesh, of freezing and storing samples, and of performing peroxide value determinations after chloroform extraction of the fat, were identical with those previously described (Tarr 1947). The l-ascorbic acid content of fish flesh was determined as follows: A known weight (usually 100 to 200 g.) was blended for not more than 30 seconds with three times its weight of water, using a Waring Blendor. Fifty ml. of the resulting suspension was promptly mixed with 50 ml. of acetic-metaphosphoric acid solution, filtered through coarse paper, and 50 ml. of the clear filtrate then

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titrated with sodium dichlorbenzenoneindophenol indicator. The solutions employed were prepared and standardized according to the official method of the Association of Official Agricultural Chemists (1945). It was found that, providing all procedures were carried out very rapidly in order to avoid oxidation of ascorbic acid, recoveries of from 99 to 100% of the theoretical amount could be realized when from 0.025 to 0.050% of this antioxidant was added to fish flesh.

Storage in Nitrogen or Carbon Dioxide

Preliminary tests with small samples of minced flesh from red spring salmon (*Oncorhynchus tschawytscha*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), black cod (*Anoplopoma fimbria*) and herring (*Clupea pallasii*), with and without 1% of incorporated sodium chloride, showed that storage in very high partial pressures of nitrogen or carbon dioxide gases entirely prevented fat peroxidation. Moreover, these trials showed that very great care had to be taken to prevent access of air to the containers, for a minute leak was sufficient to cause marked fat oxidation during long storage periods. In the following experiment, the results of which have been briefly described (Tarr 1946a), great care was taken to prevent diffusion of gas from, or into the containers used.

Three cast aluminum standard domestic pressure cookers were used for the gas storage tests, and since the cast aluminum was found to be quite permeable to gases such as carbon dioxide, the cookers and their lids were thoroughly impregnated with hot paraffin wax under pressure. Each lid was equipped with two brass gas cocks, and both these and the lid flanges were lubricated with a heavy laboratory-prepared rubber grease. The following fish were used:

Fresh herring. These were scaled, gibbed, washed and split.

Red spring salmon. An 8-lb. (3.6-kg.) fish which had been dressed, frozen, glazed and stored for about 4 months at approximately −28°C. was defrosted in cold running water and filleted. The fillets were skinned, and each was cut into eight pieces of roughly the same weight.

Coho salmon. Two 5-lb. (2.3-kg.) frozen fish having approximately the same storage history as the red spring salmon were cut up so that each fish yielded eight small skinned fillets.

Pink salmon. One 5-lb. (2.3-kg.) frozen fish having approximately the same storage history as the red spring salmon was cut up so that eight small skinned fillets were obtained.

Lemon sole (*Parophrys vetulus*). Eight medium-size fresh fish weighing about 1 lb. (0.5 kg.) each were filleted and the sixteen resulting fillets were skinned.

Small portions of each of several of the above types of fillets (brined and unbrined) were taken at this stage and wrapped and frozen as indicated below. These were defrosted immediately and were used to obtain the initial peroxide values (table I). Half of the fillets from each fish were wrapped individually in "M.S.T." (moisture-proof, heat-sealing, transparent) cellophane. The remainder were lightly brined by immersing them for one minute in 10% sodium chloride solution at between 2 and 5°C. and then wrapped after draining on a wire screen for about 5 minutes at room temperature. The wrapped fillets and split herring

were packed into eight standard 5-lb. waxed fillet cartons so that two cartons containing the same selection of fish, brined and unbrined, could be employed for each of four types of storage test. The cartons were placed in an experimental "plate" freezer refrigerated with calcium chloride brine, and were frozen for 3 hours. They were stored overnight at about −28°C. and subjected to the following treatments carried out at −10°C.

(1) Two cartons, one each of brined and unbrined samples, were stored in air as controls.

(2) Two cartons were placed in an aluminum container connected to a high-vacuum pump and evacuated for 45 minutes to a pressure of about 0.1 mm. of mercury. Commercial carbon dioxide gas was then run into the container until a positive pressure equivalent to approximately 10 cm. of mercury resulted.

TABLE I. Effect of storage in nitrogen or carbon dioxide gases on development of rancidity in fish samples stored at −10°C., as shown by peroxide value.

Treatment		Herring		Red spring salmon		Coho salmon		Pink salmon	Sole	
After days (no.)		40	98	40	98	40	98	40	40	98
Stored in air	Unbrined	7.5	18.4	4.7	10.0	14.0	46.9	43.0	—	45.0
	Brined	9.8	76.3	10.1	30.2	5.6	7.7	16.0	5.8	11.4
Vacuum then CO_2 added	Unbrined	0.1	0.8	0.0	0.4	0.1	0.2	0.0	0.0	1.8
	Brined	1.2	1.5	0.4	0.6	0.2	0.2	0.9	0.0	2.0
Vacuum, then nitrogen added	Unbrined	0.3	0.8	0.1	0.5	0.1	0.7	0.0	0.0	2.8
	Brined	1.1	1.5	0.4	1.4	0.1	0.4	0.6	0.0	3.1
Flushed with CO_2	Unbrined	1.4	2.8	0.9	0.7	3.0	7.3	3.6	0.8	9.7
	Brined	3.6	6.1	1.9	2.0	2.4	1.7	3.5	2.8	10.1
Initial values	Unbrined	0.1		0.0		0.0		0.0	0.0	
	Brined	0.9		0.4		0.3		1.0	0.0	

(3) Two cartons were treated as (2) above, except that commercial washed nitrogen was used in place of carbon dioxide.

(4) Two cartons were placed in an aluminum container and a steady rapid stream of commercial carbon dioxide gas was flushed through it for 30 minutes at slightly above (10 cm. of mercury) atmospheric pressure.

The containers were closed tightly and stored at −10°C. The initial positive internal pressure of 10 cm. of mercury was maintained to allow for any lowering of internal pressure due to cooling of the gas, and also to ensure that, should any slight leakage occur, it would be outward from the containers. After 40 days' storage the containers were opened and one fillet of each fish (brined and unbrined) was removed for examination. The containers were gas treated again as described above, and stored for an additional 58 days, after which the remaining

samples were tested. After both storage periods, the containers had a positive internal pressure which indicated that gas leakage had not been significant.

About one half of each fillet or split fish was used to determine the peroxide value of the fat; the remainder being cooked for a few minutes in boiling water in order to compare its flavour with that of the controls.

It will be seen (table I) that the air-stored samples gave, after storage, peroxide values which were considerably higher than the initial values, especially after 98 days. On the other hand, those which were vacuum-treated and then stored in carbon dioxide or nitrogen gas gave values after 40 and 98 days' storage which were approximately the same, or very little higher, than the initial ones, indicating that no appreciable peroxidation of the fat had occurred. A noticeable increase in peroxide values was found with the samples which had merely been placed in a container and flushed with carbon dioxide, so that sufficient oxygen to cause significant fat oxidation must have remained.

Organoleptic tests were made after both 40- and 98-day storage periods, and the following is a brief resumé of the principal differences observed. The air-stored herring and salmon samples had a marked rancid flavour after 40 days' storage, and this became very pronounced after 98 days. The sole fillets developed a peculiar taste sometimes described as the "salt-fish flavour". While the fillets which were exposed to a vacuum and then treated with carbon dioxide did not have a rancid flavour, they all developed a more or less pronounced undesirable flavour which is difficult to describe and the cause of which is uncertain. Fillets treated with carbon dioxide without previous subjection to a vacuum had a faint rancid flavour after the 98-day storage period, and all possessed the undesirable flavour referred to above. The fillets which were subjected to a vacuum and then treated with nitrogen had a very good flavour and there was no trace of rancidity. Also, the red colour of the salmon flesh was well retained.

Glazing

The effect of ice glazes formed from water or from solutions of certain antioxidants on the development of rancidity in salmon steaks or fillets has already been described briefly (Tarr 1946b). The results obtained in three typical experiments are recorded herewith.

Six steaks about 1.5 to 2.0 cm. thick (weight 124 to 169 g.), were sawn from a red spring salmon and from a coho salmon, both of which had been dressed, frozen in still air, glazed with ice formed from ordinary water and stored approximately 5 months at about −28°C. After weighing them, two steaks from each fish were left untreated, two were glazed with ice formed from distilled water and two with an 0.5% solution of ethyl gallate. Glazing was carried out in a room at about −18°C., the steaks being immersed for one minute in solutions at 2 to 3°C. Glazing was found to increase the weight of the steaks from 6.8 to 7.8%. The steaks were wrapped individually in moisture-proof cellophane paper and stored at −10°C. Peroxide value determinations (table II) were made at two different storage periods. It will be seen that glazing retarded, but did not prevent, fat peroxidation and that the ethyl gallate glaze was no more advantageous than the water glaze.

TABLE II. Effect of ice glazes formed from water and ethyl gallate solutions on rate of fat oxidation in salmon steaks as shown by peroxide value (initial peroxide values: red spring salmon 0.5; coho salmon 1.2).

Treatment	Red spring salmon		Coho salmon	
After days (no.)	28	79	28	79
Unglazed	2.3	17.6	3.2	21.3
Distilled water glaze	1.9	6.5	1.9	7.2
0.5% ethyl gallate glaze	1.6	5.7	1.9	5.8

Ten steaks about 2 cm. thick weighing from 165 to 231 g., cut from a fresh red spring salmon, were wrapped individually in moisture-proof cellophane paper and frozen in still air at −28°C. After one day's storage the frozen steaks were treated as follows:

They were weighed, two were left as controls and two were dipped for 10 seconds in each of the solutions the composition of which is recorded in table III. Glazing was found to increase the weight of the steaks from 5.9 to 6.9%. The glazed steaks were wrapped individually in cellophane paper and stored in wax cartons at −10°C., peroxide values being determined at intervals. The results (table III) show that glazing steaks with ice formed from ordinary water retarded the development of rancidity almost as effectively as did that from 0.5% ethyl gallate solution. On the other hand, glazes formed from 0.5% ascorbic acid solution, or from a similar solution after adjusting it to pH 6.0 with sodium hydroxide, almost entirely prevented fat oxidation.

From a fresh red spring salmon 12 steaks about 1.5 cm. thick (weight 207 to 314 g.) were cut, wrapped and frozen as in the foregoing experiment. Five of the frozen steaks were retained as controls, and five were dipped for 10 seconds in

TABLE III. Effect of ice glazes formed from water or from solutions of ethyl gallate, ascorbic acid or sodium ascorbate (pH 6.0) on rate of fat oxidation in red spring salmon steaks as shown by peroxide value (initial peroxide value zero).

Treatment	After days (no.)	
	41	84
Unglazed	4.0	8.5
Distilled water glaze	0.7	4.9
0.5% ethyl gallate glaze	0.6	1.8
0.5% i-ascorbic acid glaze	0.2	0.2
0.5% l-ascorbic acid glaze (pH 6.0)*	0.2	0.2

*An 0.5% solution of l-ascorbic was adjusted to this pH value with 1N NaOH solution immediately prior to use.

TABLE IV. Effect of ice glazes formed from water and from solutions of ascorbic acid on rate of fat oxidation in frozen red spring salmon steaks as shown by peroxide value (initial value zero).

Treatment	After days (no.)			
	98	101	252	341
Distilled water glaze	1.7	5.0	20.7	20.4
0.5% 1-ascorbic acid glaze	0.5	1.3	3.5	6.8
1.0% 1-ascorbic acid glaze	0.3	0.6	2.1	4.0

each of the solutions the composition of which is given in table IV, the temperature of the glazing liquids being between 0 and 1°C. The glazing increased the apparent weight of the steaks 5.6 to 8.5%. The steaks were wrapped individually in moisture-proof cellophane, placed in waxed cartons, and stored at −20°C. Peroxide value determinations were made at intervals. The results (table IV) show that the 1-ascorbic acid glazes were much more effective than was the water glaze, a 1% glaze causing greater protection than a 0.5% one.

DIPPING IN 1-ASCORBIC ACID SOLUTIONS

Fourteen skinned fillets about 12.5 × 7.5 × 2.0 cm. in size were cut from a fresh red spring salmon. Two fillets were dipped for 5 minutes in each of the solutions, the composition of which is given in table V, the temperature of the solutions being maintained between 2 and 5°C. The fillets were drained for about 5 minutes at 0°C., wrapped individually in cellophane paper, air-frozen at −20°C., using a fan, placed in waxed fillet cartons and stored at this temperature. Peroxide value determinations made after two different storage periods (table V) showed that dipping the fillets in 1-ascorbic acid and sodium 1-ascorbate solutions prior to freezing retarded fat oxidation strongly, and to about the same extent.

TABLE V. Effect of dipping red spring salmon steaks in 1-ascorbic acid or sodium 1-ascorbate solutions on fat oxidation during subsequent storage in the frozen state as shown by peroxide value.

Treatment	After days (no.)	
	45	122
Dipped in distilled water	2.6	7.2
Dipped in 0.025% 1-ascorbic acid	1.5	2.8
Dipped in 0.50% 1-ascorbic acid	0.3	1.6
Dipped in 1.00% 1-ascorbic acid	0.0	0.2
Dipped in 0.25% 1-ascorbic acid pH 6.0*	1.1	3.5
Dipped in 0.50% 1-ascorbic acid pH 6.0*	0.6	1.3
Dipped in 1.00% 1-ascorbic acid pH 6.0*	0.0	0.2

*Solutions adjusted to pH 6.0 with 1.0 N NaOH solution immediately before use.

TABLE VI. Influence of immersion period on the concentration of 1-ascorbic acid in red spring salmon fillets and on the rate of fat oxidation in frozen stored samples, as shown by peroxide value (initial peroxide value zero).

Immersion period in 1% 1-ascorbic acid solution (minutes)	1-Ascorbic acid content of dipped fillets %	After days (no.)		
		70	120	183
0	0.0025	3.4	10.1	13.1
5	0.0412	0.5	0.9	3.0
10	0.0565	0.3	0.5	2.3
20	0.0778	0.1	0.2	0.6

It will be seen that the rate of fat oxidation was related directly to the concentration of antioxidant in the solutions used for dipping.

From two fresh red spring salmon, twelve skinned fillets about 7.5.×6×2 cm. in size (115 to 125 g. in weight) were cut. Four fillets at a time were immersed in 1% 1-ascorbic acid solution at 1 to 2°C., three different immersion periods being employed. After draining, the 1-ascorbic acid content of one fillet from each treatment was determined (table VI), the remainder being wrapped individually

TABLE VII. Effect of 1-ascorbic acid and related compounds, of derivatives of gallic acid, and of Avenex Concentrate on development of rancidity in minced white spring salmon flesh, as shown by peroxide value.

Compound incorporated in 0.05% concentration	After days (no.)	
	116	199
Control (no compound added)	11.0	10.3
*1-Ascorbic acid	0.2	0.8
*Sodium 1-ascorbate	0.5	0.8
*d-Iso ascorbic acid	0.2	0.4
*Sodium d-iso ascorbate	0.6	1.1
*5, 6-diacetyl 1-ascorbic acid	0.0	0.5
**Ethyl gallate	0.0	1.8
†Gallate E:130#5	0.5	2.3
†Isopropyl gallate	0.5	4.7
†Isobutyl gallate	1.0	6.4
†Dimethyl ethanol ammonium gallate	5.0	5.4
†Diethyl ethanol ammonium gallate	3.1	4.4
†Ammonium gallate	2.4	5.5
†2-Ammonium 2-methyl propanol gallate	5.2	5.9
†Tris (hydroxymethyl) methyl ammonium gallate	2.4	5.7
†Morpholonium gallate	5.7	5.7
††Avenex Concentrate	8.0	10.5

*Hoffmann-LaRoche.
**"Progallin A", Nipa Chemical Co.
†Silmo Chemical Corp.
††Musher Foundation.

in cellophane paper, frozen in air at −20°C. using a fan, and stored at this temperature. The rate of fat oxidation in these fillets was found to depend directly on their l-ascorbic acid content (table VI).

Comparison of Antioxidants

Five-ml. portions of 1% aqueous solutions of the antioxidants listed in table VII were incorporated into minced white spring salmon flesh in the usual manner (Tarr 1947) to give a concentration of 0.05%. Two samples of each treatment were frozen and stored at −20°C., peroxide values being determined after 116 and 199 days' storage. The results (table VII) show that of the various antioxidants studied 5, 6 diacetyl l-ascorbic acid, l-ascorbic acid, sodium l-ascorbate, d-iso ascorbic acid and sodium, d-iso ascorbate all retarded fat oxidation very markedly. Ethyl gallate and gallate E:1305 were also very effective. The remaining gallic acid derivatives studied were all considerably less effective than ethyl gallate. Avenex concentrate proved to be a poor antioxidant.

Table VIII. Stability of l-ascorbic acid in frozen stored white spring salmon flesh.

Days stored (no.)	l-ascorbic acid in the flesh (%)	Peroxide values	
		Untreated flesh	Flesh with 0.05% l-ascorbic acid added
0	0.049	–	–
4	0.0401	–	–
4	0.0400	–	–
35	0.0371	2.5	0.8
118	0.0346	6.9	0.4
205	0.0294	–	–

Stability of l-Ascorbic Acid

l-Ascorbic acid in 0.05% concentration was blended into one portion of minced white spring salmon flesh, the remainder being left untreated. Seven 100-g. portions of each of the treated and untreated fish were wrapped in cellophane in blocks of uniform size and about 1.5 cm. thick. These were frozen in air at −20°C., using a fan, and were stored at this temperature. At intervals samples were removed and partly defrosted, and the l-ascorbic acid content and peroxide values were determined. The results, given in table VIII, show that the l-ascorbic acid content dropped sharply at first, probably during the freezing period, and then fell very slowly. Peroxide values increased much more sharply in the untreated samples than in those treated with l-ascorbic acid.

DISCUSSION

The idea that development of oxidative rancidity in flesh foods might be hindered or prevented by storage in absence of atmospheric oxygen is by no means new. Bronkhuyzen (1927) reported that fat oxidation in fish flesh could be avoided

Erratum: "E:1305" in line 12 above should read "E:130#5"

by packing it in tins in the absence of air before freezing and placing in cold storage. Callow (1933a, b) found that unfrozen pork and bacon could be stored for many weeks at 0 to 1°C. in 96 to 100% carbon dioxide, with little development of rancidity or bacterial growth. In his experiments, storage in nitrogen or hydrogen prevented rancidity development, but occasioned a taint in the flesh. While studying the effect of storage in different concentrations of carbon dioxide on the rate of bacterial spoilage of fish flesh, Weedon and Notevarp (1934) noticed that high concentrations gave noticeable protection against development of rancidity. Kong (1935) studied the effect of storage in vacuum and in carbon dioxide gas on the keeping quality of brined and freshly dried bilis fish (*Stolephorus*). In his tests a reduced pressure of 72.5 cm. of mercury proved most effective, while high carbon dioxide concentrations, although equally good from a preservative point of view, tended to cause a yellow discolouration. Recently, Bucher (1944) has reported that rancidity development in pink salmon fillets can be largely prevented when they are stored in fairly high vacuum. The present experiments have verified certain of the above observations and have extended them to show that storage of frozen fish in a very high partial pressure of carbon dioxide gas prevented fat oxidation, but that it also caused an off flavour in the fish. Storage in nitrogen gas was just as effective in preventing rancidity development and did not cause an undesirable taint. These results, as far as the production of a taint in samples stored in carbon dioxide is concerned, are at variance with those reported by Callow for meat, noted above. The reason for this development of off flavour in gas-stored frozen flesh foods is apparently not known but it may be brought about by traces of impurities in commercial gases used.

Glazing of whole fish with a film of ice before storing them has become a well-established commercial practice, but there seems to be little information available concerning the glazing of individual steaks or fillets. In 1928 Peterson obtained a patent for a process which involved washing pieces of fish or meat with a hypochlorite solution and freezing them rapidly so that they became coated with a thin layer of germicidal ice. Also, certain fishing companies have made a practice of sawing steaks from frozen fish and then glazing them with a thin film of ice in order to protect them until they are used.

The experiments described in this paper have shown that glazing fish steaks or fillets with ice formed from ordinary water decreased the rate of fat oxidation, and that a glaze formed from 0.5 or 1.0% l-ascorbic acid solution was considerably more effective in this respect. Previous work (Tarr 1947) showed that ethyl gallate, when incorporated into fish flesh in 0.02 to 0.05% concentration, was an excellent antioxidant. In the present experiments a glaze formed from an 0.5% ethyl gallate solution was only about as effective as a water glaze in retarding fat oxidation. This indicates that glazes formed from l-ascorbic acid solutions may be working as indirect antioxidants by simply removing oxygen from, and preventing its access to, treated flesh.

Individual fillet or steak glazing does not seem to be a very desirable process from a commercial standpoint, for it causes an apparent increase in weight of treated samples, the glaze may thaw and leave a quantity of free liquid in the

package, and there is a tendency for the glaze to soak into the flesh on defrosting. Antioxidant glazes for whole fish are now being investigated.

It has been found that l-ascorbic acid can readily be incorporated into fish flesh by dipping fillets or steaks into solutions of either the acid itself or its sodium salt (pH 6.0), and that both procedures appear to be equally effective. Within tested limits of 0.025 to 0.078%, l-ascorbic acid proved considerably more effective as an antioxidant for fish flesh when used in the higher than in the lower concentrations. When l-ascorbic acid was incorporated into fish flesh which was promptly frozen and stored, its concentration fell rapidly during the first day of storage and subsequently much more slowly. This indicates that there is probably a marked oxidation of l-ascorbic acid in unfrozen fish flesh, and that in frozen flesh the oxidation is relatively slow.

SUMMARY

Oxidation of flesh fats of frozen fish and development of attendant rancid or related off flavours was prevented by storing it in very high partial pressures (total pressure 10 cm. of mercury above atmospheric) of carbon dioxide or nitrogen gases. Storage in carbon dioxide caused a noticeable off flavour in all samples, which was not observed in those stored in nitrogen.

Glazing individual frozen salmon steaks or fillets with ice formed from ordinary water retarded the rate of fat oxidation when the samples were stored. A glaze formed from 0.5 or 1.0% l-ascorbic acid or sodium l-ascorbate (pH 6.0) solutions was considerably more effective in retarding oxidation of fat than an ordinary water glaze, while a glaze formed from 0.5% ethyl gallate solution was only about as effective as a water glaze.

l-Ascorbic acid was readily introduced into fish fillets or steaks by dipping them in 0.5 or 1.0% solutions either of the free acid, or of its sodium salt (pH 6.0). Both procedures gave about the same degree of protection against development of rancidity in frozen stored samples. High concentrations of l-ascorbic acid in frozen fish flesh (e.g. 0.078%) were considerably more effective than low concentrations (e.g. 0.025%) in retarding fat oxidation.

d-Iso ascorbic acid, sodium d-iso ascorbate, and 5, 6 diacetyl l-ascorbic acid gave, on a molecular basis, about the same degree of protection against oxidation of cold stored fish flesh fat as did l-ascorbic acid or its sodium salt. All these compounds were as effective, or more effective, than ethyl gallate in the same per cent concentration. Other derivatives of gallic acid were less effective than ethyl gallate, while Avenex Concentrate offered but little protection.

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REFERENCES

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. Official and tentative methods of analysis, 6th ed. 1-932, Washington, 1945.

BRONKHUYZEN, A. *Neder. Vereenig. Koeltech. Kryslog-Biolog. Proefstation Leiden, Meded.* **53**, 1927. (*Gr. Brit. Food Inv. Bd. Ind. Lit.*, **1** (1) 1929).

BUCHER, D. L. *Fishery Market News*, **6**, 1-4, 1944.

CALLOW, E. H. *Gr. Brit. Rep. Food Inv. Bd.*, **1932**, 109-112, 1933a.
Gr. Brit. Rep. Food Inv. Bd., **1932**, 112-116, 1933b.

KONG, S. M. *Rep. Fish. Dep. Str. Settlement Fed. Malay Str.*, **1935**, 44 (*Gr. Brit. Food Inv. Bd., Index Lit.*, **7**, 399, 1935).

PETERSON, P. W. U.S. Patent No. 1,689,009, 1928.

TARR, H. L. A. *Fish. Res. Bd. Can. Prog. Rep. Pac.*, **64**, 57-61, 1945.
Fish. Res. Bd. Can. Prog. Rep. Pac., **66**, 17-20, 1946a.
Fish. Res. Bd. Can. Prog. Rep. Pac., **68**, 52-54, 1946b.
J. Fish. Res. Bd. Can., **7**, 137-154, 1947.

WEEDON, H. W., AND O. NOTEVARP. *Aarsb., Norges Fisk.*, **1934**, 5, 1934.

Fertility and Fertilization of Streams

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ABSTRACT

Streams in a rather rocky and barren region in Nova Scotia were found to have almost no algae and fish except in relation to farm operations. Placing of bags of chemical fertilizer along the shore was followed in a year or two by increased quantities of algae and fish downstream, the maximum effect only 150 yards away. It is concluded that fertilizing materials are held locally in flowing water in relation to finely divided bottom material, as with soils.

Certain streams draining into Grand (Shubenacadie) lake, Nova Scotia, at the head of the bay of Fundy, were observed in 1944 to show striking differences in numbers of marked yearling salmon in September after having been planted rather uniformly with these in June. Factors found elsewhere to be correlated with survival of young salmon did not seem to explain the differences observed. There were similar differences in numbers of native young salmon and of other kinds of fishes.

The two streams showing the greatest contrast were the lower part of the Beaver river with rather many fish and the lower part of the Upper Rawdon river with no fish at all found in September. The lower part of the Beaver river runs through a farm, and abundance of fish seemed to be related to the farm operations. It is crossed at two points by fords, the lower of which is for traffic directly downhill from the barn. While some fish were found related to the upper ford and to a watering place for pastured cattle somewhat farther up, the greatest concentration of fish was just below the lower ford with scarcely any fish just above. For experimental purposes, an attempt was made on August 25, 1947, to seine out all the fish in this part of the river. The numbers of fish of various kinds and sizes obtained within 125 yards (1 yd. = 0.91 m.) downstream and 100 yards upstream from the lower ford were as given in the table below.

Table I. Numbers of fishes of different sizes obtained on August 25, 1947, in the Beaver river, N.S., within 110 yards above and 125 yards below ford from a barn.

Kind	Length in centimetres					
	2.5-4	4-6	6-10	10-14	14-22	22-33
	Above ford					
Salmo.....		3	1	1		
Anguilla....					3	
	Below ford					
Salmo.....		33	7	4	3	
Anguilla....					3	4
Catostomus .	11	72	24			
Fundulus...	8	2	8			
Cyprinidae .	155	29	3			

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The number of fish taken below the ford was 366 while only 8 were taken above, which was a very striking contrast.

The difference in growth of algae was equally striking. Masses of green filamentous algae were generally present on the bottom and coating the stones below the ford, but none were found above. There was, therefore, a considerable production of both plants and animals below the ford, but no evidence of any particular production above, since the few salmon and eels found there may well have moved into that section of the stream.

Beaver river discharges into Beaverbank lake, as do also several smaller streams that drain the land for about four miles (1 mi. = 1.6 km.) along the Beaverbank road that has a number of dwellings and partial farms. The water from Beaverbank lake flows down the Upper Rawdon river, which is half-a-mile long. Although the lower half of this river was barren of fish, there were some in its upper half, but they decreased in number from the lake outlet down as if they were related to food carried out of the lake. There are neither dwellings nor cultivated land along this river and human traffic is confined to a wood road along one side. With any fertilizing effect from above held by Beaverbank lake, the Upper Rawdon river seems not to have been fertilized by man until now.

Anadromous fishes have been considered to carry up from the sea fertilizing materials that are set free when spawning fish die. Cascades halfway up the Upper Rawdon river are said to be the upper limit for ascent of gaspereaux (*Pomolobus*) and bass (*Roccus*). It would seem that neither these nor any other migrating fish, such as eels (*Anguilla*), suckers (*Catostomus*), white perch (*Morone*), salmon (*Salmo*), trout (*Salvelinus*) and lampreys (*Petromyzon*), all of which are to be found in these waters, have served to fertilize the river.

The surrounding country is of Cambrian or Precambrian age. It is very rocky and the rocks are gold-bearing and of quartzite and slate (Goldenville and Halifax formations). The nearness of the city of Halifax (15 to 20 miles) is mainly responsible for such little cultivation of the land as is done by those who live along the roads that lead from the city to richer districts.

There is little spring water, but a great many lakes. The Upper Rawdon river drains an area of 37 square miles (1 sq. mi. = 2.59 sq. km.), of which 2¼ square miles are made up of lakes. The hills, in which the area abounds, rise to from 300 feet to 700 feet above sea level (1 ft. = 0.3 m.), with lakes nearly 500 feet up. Beaver river drops 30 feet in about a mile and Upper Rawdon river 46 feet in half-a-mile. These are fairly swift streams with successions of pools and rapids. However, the volume of flow varies greatly with rainfall. In a 17-year period (1921 to 1938), the mean flow of the Upper Rawdon river was 104 cu. ft. per sec. (1 cu. ft. = 0.028 cu. m.), the range being from 0.1 to 1,450 cu. ft. per sec. (Chisholm 1942). The monthly mean has been as high as 356 and as low as 0.5 cu. ft. per sec. In 1946 the means for July and August were 0.9 and 0.7, yet the July mean has been as high as 137 and the August mean as high as 145 cu. ft. per sec.

In 1945, it was decided to test the effectiveness of fertilizing the lower part of the Upper Rawdon river. Dr. M. W. Smith and Dr. S. A. Beatty, who had had experience in fertilizing lakes and ponds, were consulted. Inquiry failed to reveal that any attempt had ever been made to fertilize a stream. It was feared that

the fertilizing materials might merely be carried down into the lake below. Therefore, gradual introduction of the fertilizer seemed desirable. Circumstances were against taking any more than the simplest measures. Two methods were used. On July 24, 375 lb. (1 lb. = 0.45 kg.) of "C. I. L. 4-12-6" were scattered over a small area of the river bank below the cascades and a 125-lb. bag was placed upright in a pool against the bank a short distance down. On September 20, bottom samples were taken and given to Dr. F. P. Ide for assessment of the insect larvae. The results indicated that the fertilization, no matter of which sort, had been effective, particularly at the lower end of the stream, in producing a rather large population of small insect larvae of kinds that live upon locally grown plants. Circumstances did not permit very accurate assessment. The discharge during this period had varied from 2.3 to 14.8 cu. ft. per sec. On September 5, 1946, a brief attempt was made to discover any effect in occurrence of fish. No fish were found except at the head of the pool in which the bag of fertilizer had been placed, and there a dozen small cyprinids, a yearling sucker and a 9-in. (22.9 cm.) eel were taken. This seemed at the time too local an effect to be properly referable to the fertilization.

In 1946, on July 3, a second fertilization was carried out by placing three 125-lb. bags of "C. I. L. 4-12-6" on one side of the pool at the foot of the cascades, one under water, one at the water's edge and one on the bank to be covered by high water. On August 12, 1947, no trace was found of the lowest bag, there were slight remains of fertilizer from the middle bag and the fertilizer of the highest bag was largely still in place and covered with a heavy growth of algae. Cursory seining gave the first native salmon to be found in this part as well as other fish (eels and Cyprinids), and at all places tried. On August 22, 203 seine hauls were made over the quarter-mile stretch from the cascades to the river mouth. Salmon, eels, suckers, *Fundulus* and Cyprinids were taken. The number of fish per 10 hauls was graded, being greatest within 150 yards downstream from the points of fertilization in 1946 (3.75; 7.5; unseined; 4.14; unseined; 2.9; 2.5).

A possibly better measure of abundance is the number of fish taken per 100 yd. on the basis of 6 hauls per 10 yd. This gives a similarly graded distribution, the numbers for successive sections being: 23; 45; unseined; 25; unseined; 17;15. This result is illustrated graphically in figure 1. Masses of filamentous green algae were conspicuous at this time, and most were found where there were most fish. There was a definite relation of algae to relatively quiet water with silt bottom. In the extreme case, a solid bank of algae from bottom to surface stretched across the 11-yd. mouth of, but not inside, a side water with mud bottom and growth of pickerel weed and other aquatic plants. The algae were to be found all the way to the mouth of the river and for some distance along the adjacent lake shore.

Since farm operations seemed to have fertilized Beaver river effectively, a farm fertilizer was used. It is stated that "C. I. L. 4-12-6" contains 4 lb. total nitrogen, 12 lb. available phosphoric acid and 6 lb. water soluble potash per 100 lb. The nitrogen is obtained from ammonium nitrate, ammonium sulphate and cyanamide. The available phosphoric acid is obtained from superphosphate (20% P_2O_5). The potash is obtained from potassium chloride. The conditioner

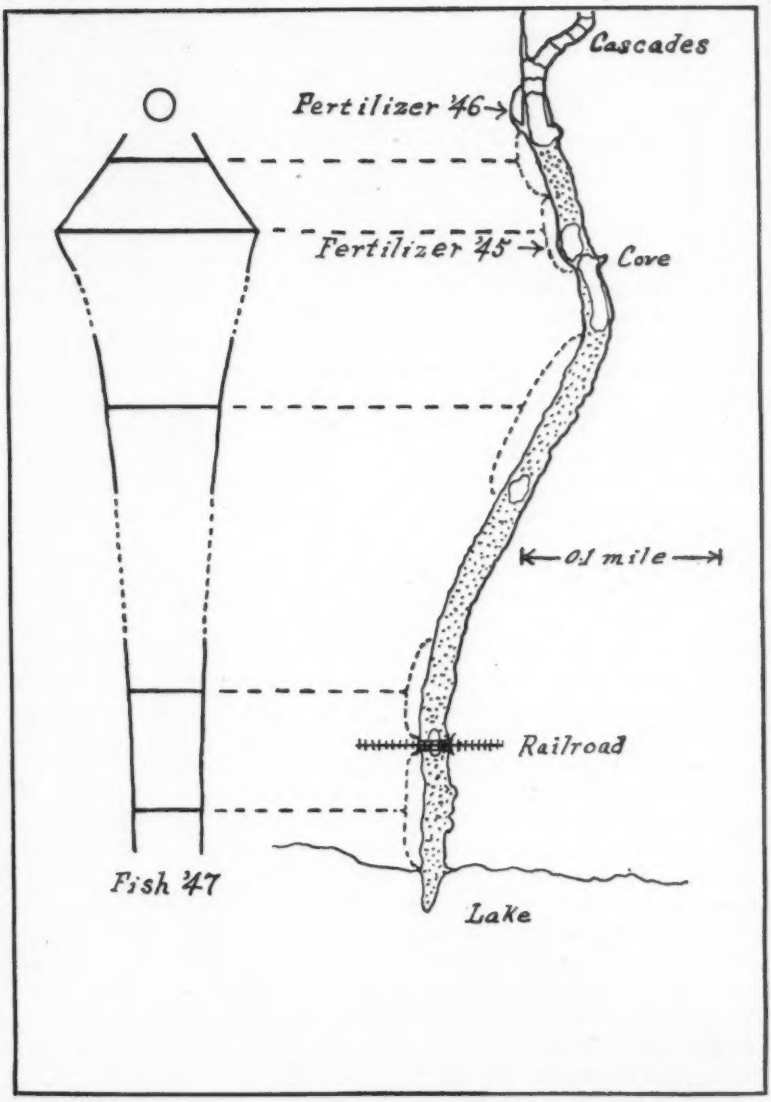

FIGURE 1. Lower part of Upper Rawdon river, N.S., on right, showing where fertilizer was placed in 1945 and 1946 and what parts were seined in 1947. Diagram on left shows relative abundance of fish as represented by numbers per 100 yds. with 6 hauls per 10 yds.

is dolomitic limestone—approx. 40 to 45% magnesium carbonate and 45 to 50% calcium carbonate.

The flow of the river subsequent to fertilization in 1946 was very slight for three months (less than 7 cu. ft. per sec. for 82 days) and ranged from as low as 0.1 cu. ft. per sec. in August to a fall high of 255 in September, a winter high of 1,100 in December, a spring high of 1,190 in May and down to 1.2 by Aug. 22.

DISCUSSION

That the fertilization would have some effect was to be expected, but that the chief effect would be such a short distance downstream was not expected. The experiment and the conditions with farm operations agree in showing a pronounced effect just below the point of application.

There is a welter of possibilities as to how the effect was produced. Experimental analysis, for which no opportunity presents, is much to be desired in order to reveal what substances were responsible, in what state they were transported and in what state they were held locally. Were they in solution or not? Were they in solid form, adsorbed on bottom material, chemically combined with other substances, or taken up by organisms? It can merely be stated that significant plant nutrients were fixed by bottom material, but not so firmly as to prevent their being absorbed by plants.

An outstanding point is the demonstration of remarkably local fertility in shallow streams. This means that fertility is not dependent upon substances in the flowing water, but upon the bottom material. It is a soil problem in spite of the steady leaching to which that soil is subjected. As with soils, the chief effect was where there was most very finely divided bottom material presenting an immense solid-liquid surface for action. The striking illustration of this was the bank of filamentous green algae, nearly a foot high, extending from bottom to surface and for 11 yds. across the mouth of a short, triangular side-water only 150 yds. below the fertilizing point. The bank of algae was so firm that a frog was sitting on the top. It was neither in the flowing water of the stream nor inside the sidewater, but where they joined and where silt brought down by the stream would settle. That these algae merely rested on the bottom is worth noting, since the rooted aquatics growing in the mud inside the sidewater were in a different category. The way in which plant nutrients may be held very locally by soils has been shown by long agricultural experiments. "Even when heavy dressings of dung are annually applied at Rothamstead there is, after fifty years, no appreciable enrichment of the subsoil in nitrogen (Table 40)" (Russell 1937, p. 223). This was found also for application of ammonium salts. The purification of sewage by land treatment and the filtration of water show similar effects.

It may be presumed that this picture would not have developed, or at least would not have been so clear, if the region had not been so barren of nutrient materials for plants. This barrenness seemed to provide a favourable background for experiment.

Attention may be called to the favourable conditions that streams present for experiments in fertilization. On the one hand, the effects will be only down-

stream from the point of application, leaving upstream water to serve as a control. On the other hand, there is the ready possibility of separating the action of the water and of varied bottom materials.

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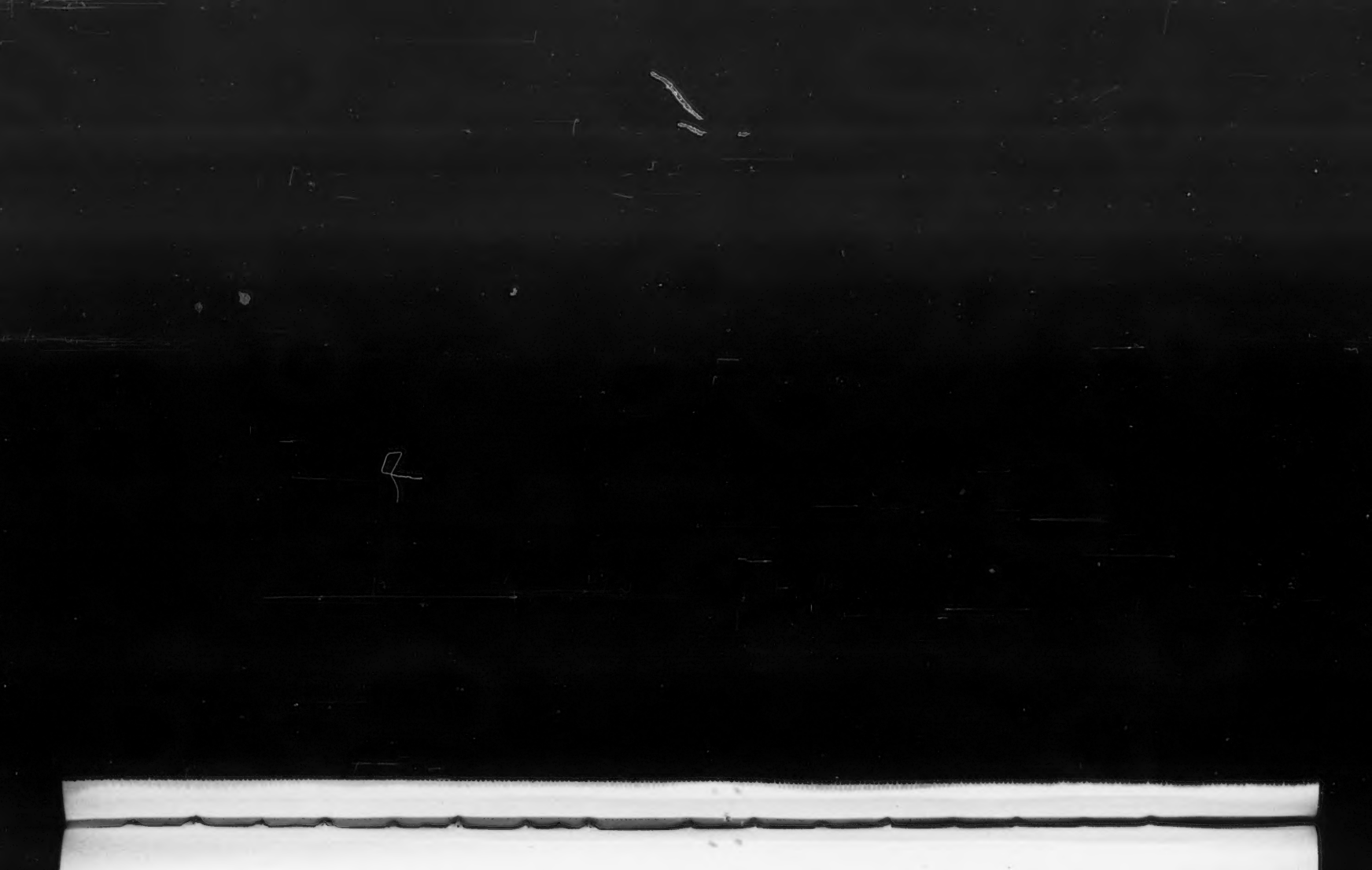
REFERENCES

CHISHOLM, K. G. Atlantic drainage . . . 1936-37 and 1937-38. *Dom. Water and Power Bur., Water Res. Pap.* **83**, 1-66, 1942.

RUSSELL, E. J. Soil conditions and plant growth. Ed. 7, 1-655, London, etc., 1937.